Relative Value of Fish Meal Versus Solvent Soybean Meal for Lactating Dairy Cows Fed Alfalfa Silage as Sole Forage[1]

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ABSTRACT

Fish meal was compared with soybean meal in three trials. In trial 1, 20 early lactation cows fed 70% alfalfa silage received an average .46 kg of CP/d from either source in 2 × 2 Latin squares. Rumen protein escapes estimated in vitro were 37% (soybean meal) and 60% (fish meal). Fish meal increased BW gain, milk protein content, yield of milk, FCM, protein, and lactose; lowered rumen propionate; and increased rumen acetate:propionate. In trial 2, 32 midlactation cows fed 89% alfalfa silage were divided into two groups of 16 and supplemented with 0, 1.5, 3.0, or 4.5% CP from either soybean meal or fish meal in 4 × 4 Latin squares. Rumen protein escapes estimated in vitro were 31% (soybean meal) and 67% (fish meal). There were linear increases in BW gain and in yield of milk, protein, lactose, and SNF with either protein but no differences between proteins. In trial 3, 32 early lactation cows fed 56% alfalfa silage received no protein supplement or an average .55 kg CP/d from soybean meal, high solubles fish meal, or low solubles fish meal in 4 × 4 Latin squares. Rumen protein escapes estimated in vitro were 27% (soybean meal), 43% (high solubles fish meal), and 63% (low solubles fish meal). Protein increased yield of milk, FCM, fat, protein, lactose, and SNF versus no supplement. Milk protein content increased about .1 percentage unit with both fish meals. Protein yield increased 61, 95, and 130 g/d with soybean meal, high solubles fish meal, and low solubles fish meal versus no supplement. In all trials, fish meal slightly reduced milk lactose content but did not alter milk fat content. Results indicated that greater rumen escape of fish meal protein, relative to soybean meal, increased efficiency of protein utilization in lactating cows fed alfalfa silage.
(**Key words**: fish meal, alfalfa silage, milk production, protein utilization)

Abbreviation key: **CPE** = crude protein equivalent, **FM** = fish meal, **HSFM** = high solubles fish meal, **LSFM** = low solubles fish meal, **SBM** = soybean meal, **SRF** = strained rumen fluid, **TAA** = total amino acids, **UIP** = undegraded intake protein.

INTRODUCTION

Alfalfa represents a major protein source for lactating cows. However, experimental evidence indicates that excessive rumen degradation of alfalfa protein results in inefficient utilization and depressed production of milk and milk protein. Broderick (4) found that although production of milk and fat were comparable, cows yielded less protein and milk with depressed protein content when fed alfalfa silage or hay than when fed corn silage-based diets supplemented with soybean meal (SBM).

There is a strong trend toward increased feeding of alfalfa silage to dairy cattle. The NRC (19) reported that undegraded intake protein (UIP) of alfalfa silage was 18% less than alfalfa hay. The NPN content of alfalfa silage typically ranges from about 60% (9) to as high as 87% (17) of total N. Cows fed all alfalfa silage diets containing 21% CP (DM basis)

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[1]Mention of commercial products in this paper is for purposes of identification only and does not constitute endorsement by the USDA or the Agricultural Research Service.

TABLE 1. Composition of protein supplements.[1]

Components	Trial 1		Trial 2		Trial 3		
	SBM	FM	SBM	FM	SBM	HSFM	LSFM
CP, % DM	47.8	69.2	47.2	68.5	48.4	68.3	67.8
Ether extract, % DM	.1	7.3	.2	5.2	.8	9.9	6.4
ADIN, % N	1.10	.76	.87	.72	1.06	.56	.50
Degradation rate[2]							
(k_d), /h	.096	.031	.133	.028	.157	.066	.034
SE	.011	.007	.016	.004	.003	.001	.001
Intercept (B), %	96.7	91.3	99.0	97.7	98.8	97.2	97.8
SE	.5	1.4	.5	.4	.3	.8	.1
Estimated ruminal escape,[3]%	37	60	31	67	27	46	63
SE	2	6	2	3	1	1	2

[1]SBM = Solvent-extracted soybean meal; FM = fish meal; HSFM = high solubles fish meal; LSFM = low solubles fish meal.

[2]Ruminal degradation rate determined with an inhibitor in vitro system (6).

[3]Estimated ruminal escape, % = $B \times [k_p/(k_p + k_d)]$, where it is assumed that ruminal passage rate, k_p = .06/h (6).

yielded more milk and milk protein when abomasally infused with casein (12). Increased production of milk and milk components was observed when alfalfa silage was treated with formic acid, or formaldehyde (18), or with a mixture of the two (14). Compared with SBM or raw soybeans, cows fed optimally roasted soybeans produced more milk and milk protein when receiving a diet containing 50% concentrate and 50% alfalfa silage (13).

Fish meal (FM) has been reported to have a mean UIP of 60% versus 35% for solvent-extracted SBM (19). The objective of these experiments was to determine whether the resistant protein in FM would be used more efficiently than that in solvent-extracted SBM in lactating dairy cows fed alfalfa silage-based diets.

MATERIALS AND METHODS

Protein Supplements

Solvent-extracted SBM was obtained from commercial sources in Madison, WI in three separate lots, one each for trials 1, 2, and 3. Two lots of Menhaden FM were obtained (Zapata-Haynie Co., Hammond, LA) for use in each of trials 1 and 2. Two additional lots of Menhaden FM, one designated as high solubles FM (HSFM) and the other as low solubles FM ("Sea Lac"; LSFM) were obtained (also from Zapata-Haynie Co.) and fed in trial 3. Two samples, prepared from weekly subsamples from each lot, were analyzed for DM, CP, and ether extract (2) and for the proportion of total N present as ADIN (15). Each sample of protein supplement also was assayed for fractional rate of protein degradation and proportion escaping the rumen using an inhibitor in vitro system (6). Mean results of these assays are in Table 1.

Trial 1

Twenty Holstein cows with means ± SE of 583 ± 15 kg of BW, parity 2.6 ± .2, 52 ± 5 d in milk, and 41.8 ± 1.3 kg of milk/d were blocked into 10 pairs of nearly equal production and stage of lactation; one of each pair was assigned randomly to group 1 or group 2. Supplemental protein from either FM or SBM was fed in a switchback experiment (2 × 2 Latin square)—group 1 began the trial with SBM and group 2 with FM. Average CP intake was .46 kg/d from FM or .47 kg/d from SBM. Supplements were fed for periods of 3 wk before switching; two complete switchback cycles were used (total 12 wk). Protein yield response to postruminal protein infusion is very rapid, occurring within 24 h (8). Hence, 1 wk was considered adequate for adaptation to protein supplementation; production data from the last 2 wk of each period were analyzed

TABLE 2. Composition of diets.[1]

Components	Trial 1		Trial 2							Trial 3			
	SBM	FM	C	S1.5	S3.0	S4.5	F1.5	F3.0	F4.5	C	SBM	HSFM	LSFM
	(% of DM)												
Alfalfa silage[2]	69.7	69.8	88.8	85.7	82.6	79.5	86.7	84.6	82.4	56.0	56.1	56.1	56.1
Corn grain	. . .	1.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
High moisture corn	25.0	25.0	9.9	9.9	10.0	10.0	9.9	9.9	10.0	42.8	37.3	39.0	39.0
Soybean meal	4.3	. . .	. . .	3.1	6.1	9.2	. . .	. . .	. . .	. . .	5.4	. . .	. . .
Fish meal	. . .	2.9	. . .	. . .	. . .	. . .	2.1	4.2	6.4	. . .	. . .	3.7	3.7
Monosodium phosphate	.4	.7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Dicalcium phosphate	. . .	. . .	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7
Trace mineral salt[3]	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
Vitamin premix[4]	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
Chemical composition													
CP	19.2	19.2	19.6	20.4	21.2	22.0	20.6	21.6	22.6	16.1	18.2	18.3	18.3
NDF	32.3	32.3	37.3	36.5	35.7	34.9	36.5	35.7	34.8	29.4	29.5	29.1	29.1
ADF	23.0	23.0	27.9	27.2	26.6	25.9	27.3	26.7	26.0	22.7	23.0	22.7	22.7
NE_L,[5] Mcal/kg	1.59	1.58	1.49	1.50	1.52	1.53	1.49	1.50	1.50	1.64	1.63	1.62	1.62

[1]SBM = Solvent-extracted soybean meal; FM = fish meal; C = negative control; S1.5, S3.0, and S4.5 = 1.5, 3.0, and 4.5% CP from SBM; F1.5, F3.0, and F4.5 = 1.5, 3.0, and 4.5% CP from FM; HSFM = high solubles fish meal; LSFM = low solubles fish meal.

[2]Alfalfa silage compositions are in Table 3.

[3]Provided (mg/kg DM): Mn, 27; Zn, 27; Fe, 17; Cu, 7; I, .40; Se, .30; and Co, .10.

[4]Provided (IU/kg DM): vitamin A, 3880; vitamin D, 730; and vitamin E, .73.

[5]Computed from NE_L values of alfalfa silage (Table 3) and NRC (19).

TABLE 3. Composition of alfalfa silages fed during the three trials.

Components	Trial 1	Trial 2	Trial 3
DM, %	38.9	43.8	36.6
CP, % DM	21.1	21.1	20.6
Ash, % DM	10.3	10.6	12.5
NDF, % DM	38.8	39.7	43.0
ADF, % DM	30.0	30.6	37.0
ADIN, % TN[1]	4.3	6.8	6.6
NPN, % TN	62.0	43.9	60.3
NH_3 N, % TN	5.8	7.9	4.9
TAAN,[2] % TN	39.3	43.8	36.3
NE_L,[3] Mcal/kg DM	1.48	1.46	1.39

[1]TN = Total N.

[2]Total amino acid N (TAA N) computed based on 40.05 mmol TAA/g N for alfalfa protein (3).

[3]Values for NE_L computed from NDF using the equation of Mertens (16).

statistically. Milk production was recorded daily at both a.m. and p.m. milkings. Milk samples were collected at one a.m. and p.m. milking midway through wk 2 and 3 of each period and analyzed for fat, protein, lactose (by infrared analysis, Wisconsin DHI Cooperative, Madison, WI), and urea (5). Cows were weighed on 3 consecutive d at the start of the trial and at the end of each period.

Diets contained (DM basis) 25% high moisture corn plus 70% alfalfa silage (Table 2) and were fed for ad libitum intake as TMR. Alfalfa silage was second cutting, wilted to 40% DM, chopped to a theoretical length of 1.0 cm, and stored in a bunker silo; alfalfa silage composition is in Table 3. Silage content of as-fed rations was adjusted at the beginning of each period based on DM determined at 60°C (48 h). Feed offered and orts were recorded daily. Feed offered was adjusted to yield 5% orts. Weekly composites of each TMR, type of orts, and silage were collected from daily samples of about .5 kg and stored at –20°C. The actual proportion of dietary DM from each component was computed from DM determined by toluene distillation (11) and at 105°C (2) for silage and concentrates, respectively. Diet ingredients were analyzed for CP and ash (2), NDF and ADF (22), and ADIN (15). Alfalfa silage was analyzed for water-soluble N and NPN (17); ammonia and total amino acid (TAA) were determined (7) in the NPN extract. Proportion of total N as TAA was computed using the TAA to N ratio in alfalfa protein without proline [40.05 mmol/g of N; (3)], because proline does not respond in the ninhydrin color assay used (7). Samples of TMR and orts were analyzed for DM (60°C, 48 h), and DMI is reported on this basis. The NE_L of alfalfa silage was computed from NDF (16). The NE_L content of the total ration was calculated using this NE_L value for alfalfa silage and NE_L reported in NRC (19) tables. Compositions of rations and alfalfa silage fed in trial 1 are in Tables 2 and 3, respectively.

Four hours after feeding on d 20 of each period, blood samples were taken from all 20 cows from the coccygeal artery or vein. Blood was heparinized and stored at 2°C for 12 h, at which time plasma was prepared, deproteinized, and then stored at –20°C until analyzed for glucose and urea (5). Also on d 20, rumen samples were taken from four additional cows fitted with rumen cannulas (two nonlactating and two in late lactation) that had been fed the experimental diets in a duplicated 2 × 2 Latin square (switchback design). Samples of strained rumen fluid (SRF), taken from the ventral sac at 0 (just prior to feeding) 1, 2, 3, 4, and 6 h after feeding were prepared by straining rumen contents through two layers of cheesecloth. The SRF was preserved by adding 1 ml of 50% (vol/vol) sulfuric acid per 50 ml of SRF and stored at –20°C. Samples were thawed and centrifuged at 30,000 × *g* for 15 min at 2°C; supernatants were analyzed for ammonia, TAA, and for individual and total VFA by gas chromatography using α-ethyl-*n*-butyrate as internal standard (5).

Mean BW change, DMI, and milk production data were analyzed as a 2 × 2 Latin

square, replicated 10 times, using the general linear models of SAS (23), including protein source, cycle, cow, and period in the model. Rumen data also were analyzed as a 2 × 2 Latin square, replicated twice, using the same model. Cow × protein source and period × protein source interactions were not significant for any parameter tested ($P \geq .16$), so neither was included in the model.

Trial 2

Thirty-two midlactation Holstein cows were divided into two groups of 16 and used in two series of 4 × 4 Latin squares. Means ± standard error for cows in the SBM group were 558 ± 19 kg of BW, parity 2.8 ± 4, 154 ± 14 d in milk, and 24.4 ± .7 kg of milk/d and for cows in the FM group were 557 ± 19 kg of BW, parity 2.3 ± .3, 155 ± 14 d in milk, and 25.4 ± .8 kg of milk/d. Within each group, cows were blocked into four squares of nearly equal production, parity, and stage of lactation and assigned randomly to four balanced 4 × 4 Latin squares. Diets contained (DM basis; Table 2) 10% high moisture corn and from 79 to 89% wilted second-cutting alfalfa silage, ensiled at 44% DM as described in trial 1 (Table 3). The four treatments within each group differed in level of supplemental CP added as either SBM or FM at the expense of alfalfa silage: 1) control (no protein supplement), 2) 1.5% CP equivalent (CPE), 3) 3.0% CPE, and 4) 4.5% CPE (Table 2). Supplements were fed for 2-wk periods before switching (total 8 wk); the 1st wk of each period was considered transitional (8), and production data were analyzed from the 2nd wk of each period. Measurements of milk production and composition, BW and feed intake, and feed sampling and analyses were as described in trial 1, except milk was not analyzed for urea but was analyzed for SNF by infrared methods (Wisconsin DHI Cooperative, Madison, WI).

Data were analyzed as a 4 × 4 Latin square, replicated four times within each protein source, using the general linear models of SAS (23). The model included protein source (FM or SBM), level (0, 1.5, 3.0, or 4.5%), period, cow within protein, and protein × level interaction (a test for different responses between FM and SBM). Significance of protein effects were hypothesis tested using cow-within-protein as the error term. Preplanned, single degrees of freedom orthogonal contrasts compared control (0 protein) versus all three protein levels for both FM and SBM; linearity of response to protein; and protein × level (slopes of responses to FM versus SBM).

Trial 3

Thirty-two early lactation Holstein cows with means ± standard error of 584 ± 10 kg of BW, parity 2.7 ± .3, 33 ± 2 d in milk, 39.0 ± 1.0 kg of milk/d, and body condition score (1.0 to 5.0) 3.3 ± .1 were blocked into eight groups of four cows each with nearly equal production, stage of lactation, parity, and condition score and assigned randomly to eight balanced 4 × 4 Latin squares. This study was conducted in two separate 12-wk cycles; 16 cows (four blocks) each were used in cycles 1 and 2. Cycle 2 began immediately after completion of cycle 1. Diets contained (DM basis; Table 2) 56% wilted third-cutting alfalfa silage, ensiled at 37% DM as described in trial 1 (Table 3), and 43% of a concentrate based on high moisture corn. The four protein sources (average CP per day) fed in the Latin squares were 1) control (no protein supplement), 2) SBM (.56 kg of CP/d), 3) HSFM (.54 kg of CP/d), and 4) LSFM (.54 kg of CP/d). Periods, measurements of BW, feed intake, milk production and composition, feed sampling and analyses, and blood sampling and analyses were as described in trial 1, except milk also was analyzed for SNF.

Data were analyzed as a 4 × 4 Latin square, replicated four times within both cycles, using the general linear models of SAS (23). The model included protein source, cycle, square, cow within square, and period within square. Cow × protein source and period × protein source interactions were not significant ($P \geq .19$), so neither was included in the model. When significant ($P < .05$) treatment effects were detected, mean separation was by least significant difference.

RESULTS

Trial 1

Compared with SBM, FM significantly ($P \leq .03$) increased BW gain, milk production, 3.5% FCM, protein, lactose, and protein concentration and slightly reduced lactose concen-

TABLE 4. Effect of supplemental protein on DMI, BW gain, production of milk and milk components, and concentrations of milk urea and plasma urea and glucose (trials 1 and 3).[1]

	Trial 1			Trial 3				
Item	SBM	FM	$P > F$	C	SBM	HSFM	LSFM	$P > F$
Mean supplemental CP, kg/d	.47	.46	. . .	0	.56	.54	.54	. . .
DMI, kg/d	22.9	23.2	.296	21.2	21.5	21.4	21.7	.617
BW Gain, kg/d	.55	1.08	.030	$-.50^{b}$	$-.01^{ab}$	$-.19^{ab}$	$.18^{a}$	.012
Milk, kg/d	36.0	37.1	.002	33.9^{c}	35.7^{b}	36.2^{ab}	36.9^{a}	<.001
3.5% FCM, kg/d	34.6	35.9	.014	32.3^{c}	34.5^{b}	34.9^{ab}	35.6^{a}	<.001
Fat, %	3.29	3.33	.500	3.23	3.32	3.33	3.31	.538
Fat, kg/d	1.18	1.23	.066	1.09^{b}	1.17^{a}	1.19^{a}	1.21^{a}	<.001
Protein, %	2.83	2.92	.010	2.81^{b}	2.84^{b}	2.90^{a}	2.93^{a}	<.001
Protein, kg/d	1.02	1.08	<.001	$.95^{d}$	1.01^{c}	1.04^{b}	1.08^{a}	<.001
Lactose, %	4.83	4.74	.074	4.94^{ab}	4.96^{a}	4.90^{bc}	4.87^{c}	<.001
Lactose, kg/d	1.72	1.76	.056	1.67^{b}	1.77^{a}	1.77^{a}	1.79^{a}	<.001
SNF, %	ND	ND	. . .	8.35^{b}	8.41^{ab}	8.43^{a}	8.44^{a}	.037
SNF, kg/d	ND	ND	. . .	2.82^{c}	2.99^{b}	3.04^{ab}	3.10^{a}	<.001
Milk urea, m*M*	7.32	7.52	.011	4.5^{b}	5.61^{a}	5.60^{a}	5.61^{a}	<.001
Plasma urea, m*M*	7.52	7.58	.861	5.51^{b}	7.03^{a}	6.98^{a}	7.02^{a}	<.001
Plasma glucose, mg/dl	59.1	59.9	.812	70.1	70.0	70.2	70.0	.999

[a,b,c,d]Means with different superscripts in trial 3 differ ($P < .05$).

[1]SBM = Solvent-extracted soybean meal; FM = fish meal; C = negative control; HSFM = high solubles fish meal; LSFM = low solubles fish meal; ND = not determined.

tration (Table 4). Also, there was a trend ($P = .07$) for increased fat production. Improvement in milk production was not large but was very consistent, indicating a modest protein deficiency on the SBM diet. Significant increases in milk protein concentration and yield were indicative of more efficient utilization of protein in FM than SBM. Assuming 2.9% protein in milk, the .06-kg of protein/d increase corresponded to about 2 kg/d of milk; this was greater than the 1.1- and 1.3-kg/d improvements in actual milk and FCM observed in this trial.

Although blood glucose and urea were not influenced by protein, milk urea was higher with supplemental FM (Table 4). The high urea concentrations in blood and milk reflected the high CP content of the diet (Table 2). There were no differences in rumen pH, ammonia, TAA, or total VFA concentrations (Table 5). However, molar proportion propionate was significantly lower ($P < .001$) with FM feeding; hence, acetate:propionate ratio was higher on the FM diet.

Trial 2

Intake, BW gain, and milk production data from trial 2 are in Table 6. The purpose of this trial was to determine the production response slopes to incremental SBM and FM as a means of quantifying the relative value of these two proteins. However, there were no differences between SBM and FM ($P \geq .31$) for any parameter measured. Although milk production averaged only 25 kg/d in this trial, addition of protein, versus no supplement, gave rise to significant, linear increases in BW gain, milk production, protein, lactose, SNF, and milk protein content and significant linear decrease in milk fat content (Contrasts A and B, Table 6). It was anticipated that if FM protein were used more efficiently, then the protein response slope for FM would exceed that for SBM. Although somewhat greater for FM, the response slopes for protein secretion were not different ($P = .25$). There was a significant protein by level interaction for milk lactose content: lactose was unchanged with SBM feeding but declined slightly with FM.

Trial 3

Feed DMI, BW change, and milk production data from trial 3 are in Table 4. Intake was unaffected by supplemental protein. However, BW change was positive on LSFM and signifi-

TABLE 5. Effect of supplemental protein on rumen pH and concentrations of N metabolites and VFA (trial 1).

Item	Soybean meal	Fish meal	*P*
pH	6.67	6.45	.189
Ammonia, m*M*	17.8	19.4	.563
Total amino acids, m*M*	3.30	1.86	.256
Total VFA, m*M*	122.2	133.8	.219
Acetate, mol/100 mol	65.1	65.4	.608
Propionate, mol/100 mol	17.7	16.6	<.001
Butyrate, mol/100 mol	11.2	11.8	.339
Isobutyrate, mol/100 mol	1.31	1.55	.568
Valerate, mol/100 mol	1.94	2.09	.112
2-Methylbutyrate + isovalerate, mol/100 mol	2.50	2.49	.777
Acetate:propionate	3.69	3.96	.011

cantly greater than the control. Weight change on SBM or HSFM was not different from the control. Production of milk and all milk components was greater ($P < .001$) with supplemental protein. Feeding any of the three proteins increased milk and 3.5% FCM an average 2.4 and 2.7 kg/d more than the control diet, increases of 7 and 8%. Average secretion of fat, protein, lactose, and SNF was increased by 10, 10, 6, and 8%, respectively, over that of the control. Supplemental protein resulted in small but significant changes in milk content of protein and lactose ($P < .001$) and of SNF ($P = .037$). Milk production and SNF tended to be greater with FM versus SBM; production was greater on LSFM than SBM, and production on HSFM was intermediate (Table 4). Fat content of milk was unaffected by diet. Milk protein content increased with the two FM compared with that of the control and SBM diets. Relative to the control, protein secretion increased stepwise with addition of SBM, HSFM, and LSFM, each response being greater ($P < .05$) than the one before (Table 4).

Concentrations of urea in milk and blood plasma and concentrations of glucose in blood

TABLE 6. Effect of levels of supplemental SBM or FM on DMI, BW gain, production of milk and milk components, and concentrations of milk urea and plasma urea, and glucose (trial 2).[1]

	% SBM protein				% FM protein					
Item	0	1.5	3.0	4.5	0	1.5	3.0	4.5	SE	Contrasts[2]
Supplemental CP, kg/d	0	.30	.60	.89	0	.29	.54	.85	. . .	
DMI, kg/d	19.8	20.9	20.8	20.3	19.1	20.4	18.8	19.5	2.0	
BW Gain, kg/d	−.13	.20	.42	.60	−.17	.42	.09	.87	.78	A**B**
Milk, kg/d	23.9	24.6	24.3	25.7	23.6	23.9	25.0	25.7	1.7	A**B**
3.5% FCM, kg/d	24.0	23.9	23.4	24.8	23.1	23.4	24.3	24.9	1.8	
Fat, %	3.53	3.33	3.31	3.32	3.36	3.37	3.31	3.30	.19	A**B*
Fat, kg/d	.84	.82	.80	.85	.80	.81	.83	.85	.07	
Protein, %	2.99	2.99	3.00	3.02	2.96	3.00	3.05	3.06	.07	A**B**
Protein, kg/d	.71	.74	.73	.77	.70	.72	.76	.79	.06	A**B**
Lactose, %	4.72	4.76	4.76	4.74	4.77	4.71	4.74	4.71	.07	C*
Lactose, kg/d	1.13	1.17	1.16	1.22	1.13	1.13	1.19	1.21	.08	A**B**
SNF, %	8.37	8.41	8.41	8.42	8.39	8.37	8.45	8.42	.10	
SNF, kg/d	2.00	2.07	2.04	2.16	1.98	2.01	2.12	2.17	.14	A**B**

[1]SBM = Solvent-extracted soybean meal; FM = fish meal.

[2]Single degree of freedom orthogonal contrasts: A = 0 protein versus all protein levels; B = linear effect; C = protein × level interaction.

*$P < .05$.

**$P < .01$.

plasma are in Table 4. Both milk and blood urea were greater ($P < .001$) when cows were fed protein relative to those of the control. Blood glucose was unaffected by dietary protein.

DISCUSSION

Estimated rumen escapes (Table 1) determined by an in vitro procedure (6) for the supplemental proteins fed in these trials were similar to those reported by the NRC (19): SBM averaged 32% UIP, FM averaged 64% UIP (trials 1 and 2), and UIP of HSFM was intermediate between SBM and LSFM (trial 3). Levels of CP, NDF, ADF, and NE_L indicated that the quality of alfalfa silage fed in these trials (Table 3) was excellent (16). However, the proportions of total N present as NPN also were high (44 to 62%, Table 3) and typical for alfalfa silage (9, 17). Low efficiency of protein utilization because of high NPN in alfalfa silage probably explained the production responses to protein supplementation in all three trials, despite CP in the basal diets (Table 2) of 16 to nearly 20%, and the significantly greater response to FM than SBM in trials 1 and 3. High levels of alfalfa silage were fed in trial 2 to make the cows more responsive to supplemental protein (12). However, milk and protein production of these midlactation cows may have been too low to quantify differences between response slopes of FM and SBM, despite estimated rumen protein escapes that were comparable with trials 1 and 3 (Table 1). Oldham et al. (20) observed greater protein production with FM versus urea in both early and midlaction cows. Wohlt et al. (27) obtained greater improvement in milk production from feeding FM than either SBM or corn gluten meal in cows fed diets with 50% corn silage. Increased production of milk and milk protein was reported with feeding increased UIP as roasted soybeans in diets containing 50% alfalfa silage (13) and as expeller SBM in diets containing 58 (9) or 75% (10) alfalfa silage.

The most unequivocal finding was increased protein yield with addition of protein, particularly FM, to the diet. In trial 1 (70% alfalfa silage), versus SBM, FM increased protein by 61 g/d. Both SBM and FM increased protein production when added to the control diet with 19.6% CP in trial 2. In trial 3, protein content increased .1 percentage unit with the two FM, compared with protein contents of the control and SBM diets; relative to control, protein secretion increased stepwise by 61, 95, and 130 g/d with addition of SBM, HSFM, and LSFM. Response to LSFM was 72% of the 180 g of protein/d obtained by Dhiman and Satter (12) with abomasal infusion of 1 kg of casein/d in early lactation cows fed only alfalfa silage. Significantly greater protein secretion with LSFM than with HSFM indicated an advantage of feeding "ruminant grade" FM with lower amounts of soluble and degradable protein. Soluble protein expressed from FM press-cake often is added back to the meal prior to drying (K. J. Short, personal communication). Previous tests showed that rumen protein escapes, estimated in vitro, ranged from 43 to 72% for 11 different FM sources (G. A. Broderick, unpublished). The NRC (19) reports UIP values of 48% of "stale" FM and 78% for "well-preserved" FM.

An interesting observation in all three trials was the small decline in lactose concentration with FM feeding (Tables 4 and 6). Milk lactose concentration often is thought to be constant because it is a regulator of milk osmotic pressure and a determinant of secretion (25). Whey, of which lactose is the principal nonwater component, is a by-product of cheese production and may become an environmental pollutant around cheese plants. The practical significance of this decrease is apt to be small because the mean change in all three trials was −.07 percentage unit.

In these studies, FM feeding at 2.9 to 6.4% of DM in diets containing 56 to 87% alfalfa silage (Table 2) did not result in any change in milk fat content; milk fat yield with FM feeding was increased in proportion to the milk production response. Rumen VFA patterns on 70% alfalfa silage (trial 1, Table 5) actually showed reduced propionate and increased acetate:propionate ratio with FM. Previously, it was observed that milk fat content and production were reduced when cows fed corn silage as sole forage were supplemented with 6% (27) or 13% FM (28). Spain et al. (24), also feeding corn silage as sole forage, found milk fat secretion was depressed with 10 and 19% FM, but not with 2 and 4% FM in the diet.

Anecdotal evidence has indicated that feeding FM, particularly when top-dressed, will

decrease feed intake in lactating dairy cows. Intake of DM was not significantly affected by feeding either SBM or FM in any of these studies; however, rations were fed as TMR in all three trials. There was increased BW gain with FM feeding to the early lactation cows in trials 1 and 3. Weight change is variable, is complicated by changes in rumen fill, and is often a poor indicator of energy status. However, comparisons among treatments within trials are appropriate. Nonsignificant increases of .3 and .2 kg/d in DMI cannot account for the .53 and .19 kg/d significantly greater weight gain with FM and LSFM, relative to SBM supplement, in trials 1 and 3 (Table 4). Increased intake would have provided only about .5 and .3 Mcal of the 2.7 and 1.0 Mcal/NE_L required (19) for these extra gains. It has been suggested that lactating dairy cows must be in positive energy balance before they come into estrus (26). The greater apparent BW gains with FM feeding may benefit reproductive status of lactating cows. Armstrong et al. (1) reported improved conception rates and reduced services per conception with FM feeding.

Blood and milk urea levels are partly reflective of rumen ammonia; it has been suggested that milk urea concentrations greater than 5 m*M* indicate excessive rumen degradable N (21). Although not determined in trial 2, milk urea concentrations averaged 7.4 m*M* in trial 1 and ranged from 4.5 to 5.6 m*M* in trial 3 (Table 4). Thus, rumen degradable N appeared adequate in trial 3 (56% alfalfa silage) but in excess in trial 1 (70% alfalfa silage). Blood and milk urea levels did not appear to be sensitive to the small differences in UIP intake among these diets. Greater blood glucose concentrations in trial 3 than trial 1 may reflect greater supply of starch and gluconeogenic precursors with higher concentrate feeding. There was no effect of protein source on blood glucose concentrations.

CONCLUSIONS

Fish meal supplementation of early lactation cows fed diets containing 56 or 70% alfalfa silage resulted in greater production of milk and milk components than SBM supplementation. Midlactation cows fed 79 to 89% alfalfa silage gave increased milk production with dietary protein addition but showed no advantage for FM versus SBM. Feeding 2.9 to 6.4% FM in TMR containing 56 to 87% alfalfa silage did not depress feed intake or milk fat content. Overall results verify the poor utilization of protein in alfalfa silage and the need for protein sources of high undegradability. There was a clear advantage in protein secretion with supplementation of FM, especially LSFM, over SBM, the protein supplement most commonly fed to dairy cattle. Greater protein production with LSFM versus HSFM indicates the importance of ensuring that "resistant" protein supplements actually are high in UIP.

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